THE BRAILLE SLIDE RULE; A TEACHERS' AND STUDENTS' GUIDE TO THE USE OF THE BRAILLE SLIDE RULE

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THE BRAILLE SLIDE RULE

A Teachers' and Students' Guide to the Use of the Braille Slide Rule.

Richard L. Montgomery

Sponsoring Committee:

Dr. P. Powers, Chairman
Dr. A.V.Keliher
Dr. W.P.Sears

Submitted in partial fulfillment of the requirements for the degree of Doctor of Education in the School of Education of New York University.

BRAILLE

Great words within! Yet (being blind),
    A fast-closed book is all they find.
But when their fingers gain this key,
    The book is open - and they see!

- Margaret Root Garvin.

SLIDE RULE

This "figuring stick" has power.
    This instrument has an abundance of speed,
It can save many an hour
    Through a universal need.

Acknowledgments

The author is grateful to his sponsoring committee, Dr. Pliny H. Powers, Chairman, Dr. Alice V. Keliher and Dr. William P. Sears, and also to the following persons for their cooperation in various ways: Professor Sylvia Emery, Skidmore College; Dean A. S. Langsford, School of Engineering and Architecture, Washington University, St. Louis; Mr. Adolf Keuffel, Jr., Keuffel and Esser Company, Hoboken, New Jersey; Mr. Robert H. Thompson, Superintendent, Missouri School for the Blind, St. Louis; Mr. Wuensch, Eugene Dietzgen Company, New York City; Mr. A. C. Ellis, Director, American Printing House for the Blind, Louisville; Mr. Richard Hoover, Johns Hopkins University, formerly with the Maryland School for the Blind, Baltimore; Mr. L. W. Rodenberg, Director, Department of Braille Printing, Illinois School for the Blind, Jacksonville; Miss Elsie A. Hug, School of Education, New York University, and my loving wife, Mabel Montgomery, who typed the manuscript and helped generously.

Richard Montgomery

T A B L E O F C O N T E N T S

Chapter I.

Early Development of the Slide Rule

The earliest means of computing were with such things as a finger drawing in sand, hand and foot measures, shadow, drops of water; then came such aids as the compass, suanpan, (16,3) abacus with its many subsequent modifications, s'choty, soroban, "bones"; and now, we have the various modern meters. Man's quest for finer measures of accuracy still goes on. Shuster (16,8) points out that this total accomplishment of civilized man, in our place-value number system, is the most remarkable acievement in history and that it is not due to one man, race, or age but to the composite of all the best mathematical thinkers.

The principle of the slide rule is only a portion of this total composite and we shall see how some of the leading scientists contributed their part to make the slide rule what it is today.

Though based decimally the slide rule did not initiate the use of decimal fractions. Back in 1530, the first computations with decimal fractions were made by Christian Rudolff. About 50 years later, Stevin went further and extended the use of decimal fractions by many illustrations and explanations.

John Napier (1550-1617), a Scottish mathematician, produced his system of logarithms in 1614. This was like "a bolt from the blue," says Lord Moulton, for nothing to that date had been done on the subject. Quoting Napier himself through one of Breckenridge's manuals (1c,20):

> Seeing there is nothing (right well beloved Students of Mathematics) that is so troublesome to mathematical practice, nor doth more molest and hinder calculators, than the multiplications, division, square and cubical

> extractions of great numbers, which besides the tedious expense of time are for the most part subject to many slippery errors, I began therefore to consider in my mind by what certain and ready art I might remove these hindrances.

His "Canon of Logarithms" or Napier's "Descriptio," or Napier's "Bones or Rods," as sometimes called, is directly responsible for the invention of our slide rule of today. The miraculous powers of instruments in modern computation is largely due to this invention of logarithms.

Henry Briggs, in 1615, assisted his friend John Napier and, produced his work on Logarithms. He, , later, coined the term "mantissa" and suggested the word "characteristic." As we know, these two terms are today very common.

Jobst Burgi, a Swiss, in 1620 at Prag published his works on logarithms. His study was independent of those of both John Napier and Henry Briggs. In the same year, 1620, Edmund Gunter designed a "Line of Numbers." This was a series of logarithanic numbers scaled along a straight line, with computations made by a compass.

William Oughtred, in about 1622, invented circular and linear slide rules (4,46). After Napier published his work on logarithms, Gunter made a logarithmic scale and used a pair of dividers for his computations instead of a sliding parallel scale as we use today. Credit is given to the Englishman Oughtred (born in 1574-died 1660) for being the first to use a double scale and he is referred to today as the "Father of the slide rule." His great love for mathematics brought about the invention of this remarkable and powerful tool of education. Cajori, an outstanding author in mathematics, (4,46) in his excellent treatise on the "Father of the slide rule" states:

> Oughtred's most original line of scientific activity is the one least known to the present generation .... The invention of the slide rule has .... been a matter of dispute; it has been erroneously ascribed to Edmund Gunther, Edmund Wingate, Seth Partridge and others. We have been able to establish that William Oughtred was the first inventor of slide rules, though not the first to publish thereon. We shall see that Oughtred invented slide rules about 1622 but the descriptions of his instruments were not put into print before 1632 and 1633. Meanwhile one of his own pupils, Richard Delamain,who probably invented the circular slide rule independently published a description in 1630 at London, in a pamphlet of 32 pages entitled Grammelogia; or the Mathematical Ring .... Thus Delamain antidates Oughtred two years in the publication of a description of a circular slide rule. But Oughtred had invented also a rectilinear slide rule, a description of which appeared in 1633. To the invention of this Oughtred has a clear title.

Again, wishing to illustrate Oughtred's cleverness, Cajori (4.5) points to his youth before the time of watches and pendulum clocks:

> At the age of twenty-three Oughtred invented his Easy Way of Delineating Sun-Dials by Geometry which through was not published until about a half a century later, in the first English edition of Oughtred's Clavis Mathematicae in 1647

Cajori further states that William Oughtred by profession was a minister of the gospel. His mathematical achievements were a product of a hobby carried on during his leisure time. Often, he would go through nights without sleep to carry on his studies. He was extremely generous to others in teaching mathematics, free of charges, and even boarding his students for months during their studies without cost. Many sacrifices were made on his part to help others. His personal health, his finances, his social life and even his parish were neglected to pursue this interest in mathematics.

Edmund Wingate in 1628 produced his "Construction and Rise of the Line of Proportion."

William Forster, a student of Oughtred, wrote "The Circle of Porportion and the Horizontal Instrument," London,1632 and 1633. In these rests the proof that Oughtred is the inventer of the slide and circular rules.

Hartwell in 1646 simplified logarithm to such a degree, he was able to introduce it to elementary arithmetic. His introduction made it possible to present this branch of mathematics to young people on a wide scale.

Robert Bisraker in 1654 produced a slide rule which looks like the modern type. He made it for a friend known only as "T.W."

Henry Coggeshall's pamphlet, 1677, describes his slide rule, used in measuring timber. This went through seven editions, last being in 1767. His slide rule was very popular and it was used as late as 1874 even later.

Sir Isaac Newton (1642-1727), in addition to all of his other brilliant achievements in the scientific world, contributed to the slide rule invaluably. To him goes the credit of the first use of the indicator and solution of the cubic equation.

At this point, (digressing from the calendar of events related to the slide rule,)Nicholaus Saunderson, (born in January,1682, died April 19,1729) who was a close friend (31,67) of Sir Isaac Newton and a blind mathematician, invented the slate for the blind for their mathematical computations in 1720 (35,85). It was Saunderson who succeeded

Newton as professor of mathematics at Cambridge University upon the latter's recommendation. For these outstanding accomplishments Saunderson was given the Doctor of Laws by King George in 1728. (See page 8, Saunderson's Slate)

Warner in 1722 made extensive use of the cube scales as well as the square scales.

Thomas Everard, an excise officer, in 1755 made wider use of the slide rule in engineering and the first appearance of the inverted scales is attributed to him. His popular book "Gauging" went through ten editions.

William Nicholson in 1789 produced a good description of slide rules up to that date and designed a new type of slide rule of a spiral form. About the same time Jean B. Clairout brought about through his experimentations a new type of circular slide rule.

Peter M.Roget, M.D., in 1815 produced the LL (log log) scale. For a while, this scale was forgotten until thermodynamics, electrical and other physical calculations revived its use.

Lt. Amédee Mannheim in 1859, while making calculations for the French Artillery, invented the present form of our slide rule which continues to bear his name - Mannheim Slide Rule. It was Mannheim who successfully popularized the runner which was invented by Newton nearly 200 years before. The slide itself has other scales on its reverse side and the top horizontal edge of the body is ruled.

Edwin Thacher in 1881 devised a cylindrical type of slide rule, which bears his name. It is believed to be the most accurate of all slide rules to date.

William Cox in 1891 produced a Duplex type of slide rule, which is widely used today.

Florian A. Cajori in 1909 wrote "The history of the Logarithmic Slide Rule and allied instruments." This document is outstanding and is invaluable to the general field of mathematics.

The early slide rules were made of metal, bone, wood and ivory. Some were beautifully engraved by hand. Most slide rules today are made of seasoned wood, celluloid or plastics while all types of slide rules are engine divided and marked. These instruments measure from 3 inches in diameter to 6 feet in length and weigh from 3 ounces to 50 pounds. Most of them are 10 inches in length and weight about 4 or 5 ounces.

During the last three hundred years, the slide rule has had varying degrees and waves of popularity. Experts' and specialists' use of it stimulated the high peaks of demand.

With the many slide rules invented for varied uses today, dozens may be found on the market. Their uses meet the needs of merchants, architects, surveyors, builders, chemists, engineers, machinists, teachers, astronomers, navigators, students, draftsmen, mathematicians, statisticians, and physicists.

Among the many scales on slide rules, we find, A, B, C, CF, CI, CIF, D, DF, DI, DIF, K, L, LL0, LL00, LL1, LL2, LL3, S, St, Sh1, Sh2, T, Th, also pi scales and scales for dividing years into twelfths instead of tenths. Other scales have been invented to facilitate calculations and conversions,

in the office, laboratory and workshop. Another recent scale, not available to civilians, was made by the Ordnance Department of the United States Army. This scale facilitates the computing of quantities of foods for soldiers.

In the fall of 1923, the candidate, then a freshman at the University of Texas, began various experiments with log scales on circular, triangular, rectilinear, and square forms. New York Point and log scales were embossed upon metal which was attached to three pieces of grooved wood. This crude rule, Cedrule (32,74) as student friends referred to it, supplied satisfactory answers to problems in physics and mathematics courses taken at that time. Later, the rule was doubled in width and length to accommodate tertiary readings and braille supplanted New York Point. In 1925 and 1938 when attempts were made to carry on further experiments with the braille slide rule at the New York Institute for the Education of the Blind, the candidate met with refusals. Dr. Paul V. West, in a statistics course, in 1933, made the first suggestion that the braille rule be patented and with his encouragement, eventually the candidate secured a patent for the first braille slide rule. (See Fig. 1. The Braille Slide Rule)

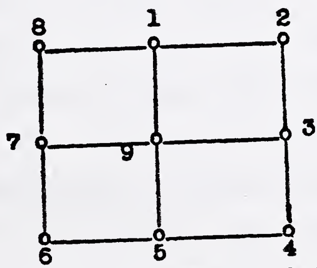
Although the slide rule today is a little over 300 years old, this period of time encompasses the long search by man to make this instrument more accurate and useful. The slate, a little over 200 years old, is still used today by the blind. Through a number of studies (39), (40,8), (30,6) and experiments concerning the slate, it has been revealed that slate is still slow in computation

cumbersome to handle, a small area upon which the problems may be solved, and difficult for the student to carry the slate to and from the school. The braille slide rule had its birth because of above needs. It offers ease in handling, speed and accuracy in computations, and is easily carried to and from class rooms. Speaking of newer methods in arithmetic Illinsworth says (35,159) ".... if there is one error more than another into which a blind teacher is liable to fall, it is the fault of over-conservativeness in methods of teaching (arithmetic) and a general reluctance to accept what is new."*

(See page 18, The Braille Slide Rule).

Saunderson's "first idea of a tangible aid to arithmetic led him to the construction of a board divided into square spaces which he cut for himself. Each space was provided with

Saunderson's Slate



a pinhole at each corner, midway on each side, and in the centre, making nine holes in all. By means of two pins placed in varied positions in these holes relative to the sides and centre of the square he obtained his nine digits. When the square remained unoccupied by pins, it represented a nought." (35,86)

*A paper read at the International Congress, Paris, July 1900 by W.H.Illingsworth, then Headmaster of the Royal Blind Asylum and School, West Craigmillar, Edinburgh.

Chapter II.

Early Development of the Braille Point System

The picture of two men initiating the idea of the slide rule on the British Isles is similar to a picture of two men starting the braille system for reading two hundred years later in France. John Napier and William Oughtred produced the basis for the slide rule in the early 1600's while Charles Barbier (1819) and Louis Braille (about 1828) created the universally adopted method for reading by the blind, the braille system. However, the outstanding contributions in the education of the blind actually began with the works of Saunderson, Diderot and Haüy.

M. Diderot, who was a physician to King Louis XV of France, an author, a philosopher and a French encyclopedist, wrote what is thought to be the first piece of literature, "Essay on Blindness," dealing wholly with the blind. (35,1) His enthusiasm and rationalized writings, suggesting the potentialities of the blind, brought about his imprisonment (45,159).

Haüy, of whom Illingsworth said that all (31) schools for the blind should place his name in gold on their wall, is the first educator of the blind. "In 1784 he induced a young beggar, (45,160) Francois Leseuer, to be his pupil, and the next year, with the aid of the French Philanthropic Society, opened the first school for the blind," in Paris.

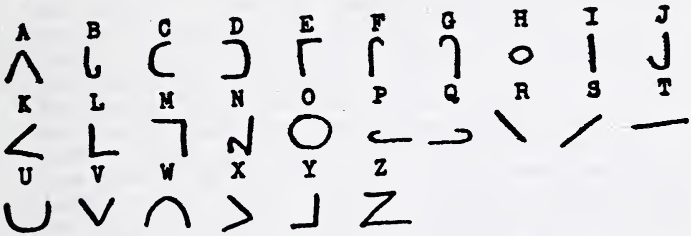
Haüy, in his notable "Essay on the Education of the Blind" (35,6), dedicated to the King of France in 1786, gives this inkling of the period before his discoveries: Before our

time various but ineffectual experiments had been tried ...."
Concerning the crudity of the instruments for the blind, he mentions .... "these gross and imperfect utensils ...." Valentin Haüy was (35,4) born in 1745 and died in 1822.

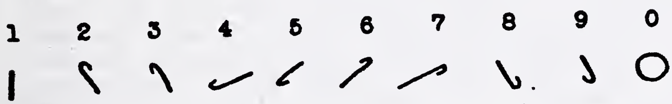
In 1847 a new type of reading began to gain popularity. In 1884, moon type, raised line for reading, was in vogue in most British schools for the blind.

Facsimile of the Moon Type

Alphabet



Numerals



Invented by Dr. William Moon (31,129), born in 1817 in England, it is most frequently used by adult blind who have lost sight in later life and who, because of hard manual work with their hands or advanced age, have less sensitivity in their fingers.

Of Barbier and Braille, Rodenberg of the Illinois School for Blind, has written excellent sketches (45,161)

.... Charles Barbier - an engineer and cavalry officer interested in signal codes, brought forward the first system of points in arbitrary arrangement. He grouped his points in successive "cells" along the line, each cell containing twelve possible points arranged six high and two wide. He invented a writing board with grooves over which the paper could be laid and impressed with a stylus. Over the paper was fixed a thin metal plate with window-like openings to guide the stylus to the positions of dots in the cells. Barbier's system was exhibited at the institution where its possibilities tantalized more than one imagination. It was phonetic, like shorthand, instead of alphabetic; the characters were too tall for the finger tips; the

the constructions were complicated; yet here was the real genesis of great things to be. Barbier was the father of point reading.

Barbier's cell

Rodenberg continues:

In a little old stone hut at the foot of the stony hill of the village of Coupvray, twenty-six miles east of Paris beyond the Marne, Louis Braille was born on January 4,1809. His father was a harness-maker. At the age of three the child blinded himself while playing with one of his father's awls. At the age of ten he was sent to the Paris institution for the young blind. At seventeen he was made a junior master and at nineteen an instructor. .... Louis Braille, before he was twenty, through some inspiration of which there is no record, designed an alphabet of the upper half of the Barbier cell. The braille cell, then, became three points high and two wide. His constructions of signs were systematic in the extreme, though brilliant and simple. Out of the upper four points he made ten basic characters, and from these in turn he made thirty more by adding points from the third level, first the lower left point, then both lower points, and finally the lower right point. Without going farther into this system, suffice it to say that the arrangement of all sixty-three characters possible in the two-by-three cell was cleverly methodical. In the main he seems to have disregarded the fact that some of these characters are more legible than others and that certain letters of the alphabet occur much more frequently than others. Louis Braille used no shorthand signs, as did Barbier, and would probably have objected to the contractions or abbreviations of words now a days. By 1834 he had worked out his system in great detail, including a musical notation which, in all of its essentials, remains to the present time capable of presenting to the blihd all varieties of musical composition.

He held organ posts in churches of Paris, being a musician of considerable ability. It is said that he was permitted to teach his point system to only a few pupils after hours. All his life he was without robust health. His death occurred in 1852, two years before his system was officially established in the institution where for a quarter of a century his genius had worked so modestly and so effectively.

Braille's cell

T. R. Armitage was born (35,91) in Tilgate Hall, Sussex in 1824. He has been referred to as the "Great Missionary of Braille" and his work with his organized body, the

British and Foreign Blind Association of 1868, was outstanding.

It is interesting to note another parallel occurring in St. Louis,Missouri. Washington University was the first educational institution to require its engineers to use the slide rule (1880); while Dr. Simon Poolak of the newly opened Missouri School for the Blind was the first leader to adopt braille (31,158) point in America, (1859).

William Wait during 1859-1863 performed his experiments and for many subsequent years, as director (31,135) of the New York Institute, influenced most schools to adopt the New York Point. This system utilized points two high and four wide. However, some confusion still exists as to the origination of this system: whether he was the inventor or his predecessor, Dr. John D. Russ, first director of the New York Institute for the Education of the blind, which opened in 1832.

New York Point

Alphabet

a	bb	c	d	e	f	g	h	i	j
••	•••	••	••	•	•••	•	••	•	•••
•	•	•	•			•••	•••	•	•

k	l	m	n	o	p	q	r	s	t
•••	•	••		•	•	•	•	•	
•	••	•	••	•	••	•••	••	•	•

u	v	w	x	y	z
	• •	•	• •	•	•••
•••	•	••	•••	• •	••

Numerals

1	2	3	4	5	6	7	8	9	0
••	••	•	••	••	•	•	•	•	•
••		••	•	•	••	•	•	•	

Number sign •••
•••

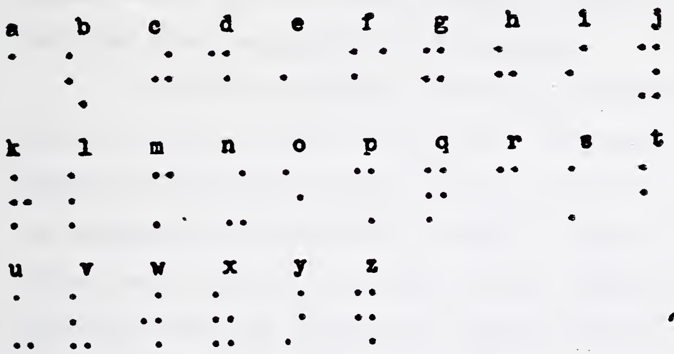
Example,		1	9	4	4
	•••	••	•	••	••
	•••	••	•	•	•

The American Association of Instructors of the Blind was organized in 1871 and the international congress of teachers of the blind first met in 1873 in Vienna.

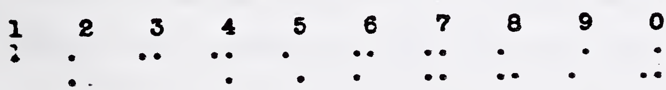
Joel W. Smith, in 1878, introduced a system called the American Braille.

The American Braille

Alphabet



Numerals



Number sign

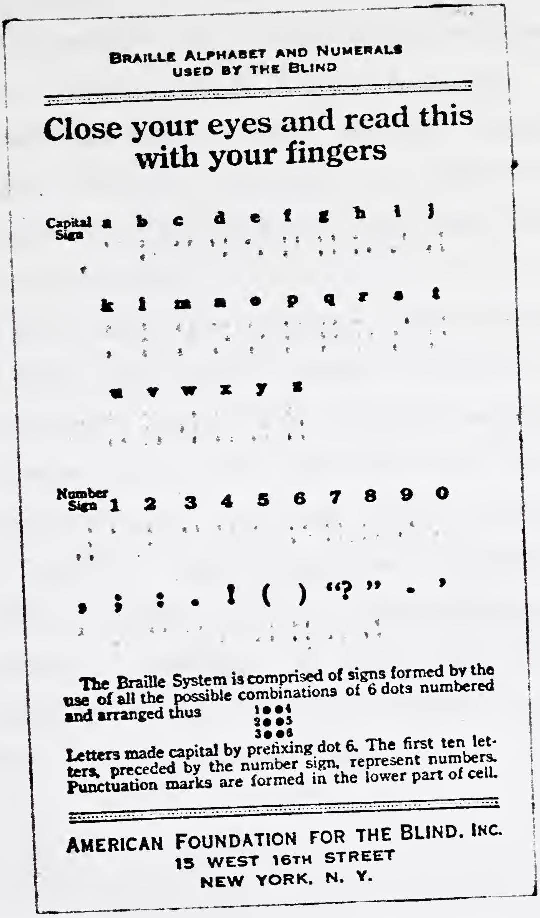
Frank H.Hall, Superintendent of the Illinois School for Blind, between 1890 and 1892 experimented upon and finally invented the braille typewriter. This achievement was and still is recognized as remarkable.

In 1905, a vigorous group, after ten years of notable work, became known as the American Association of Workers for the Blind. Their continued good work led to the proposal of

their own Standard Dot about 1915. This system contained elements of both orthodox braille and New York Point. In 1905, the British produced another system, the Revised Braille, which had three grades: grade one included words spelled in full, without contraction; grade two employed a few contractions; while grade three consisted of highly contracted and condensed words. Later, the Americans selected a part of grade two which was then known as grade one and a half.

H.Randolph Latimer, Principal of the Maryland School for the Blind, a blind man himself, originated the idea of the American Foundation for the Blind, and with M. C. Migel, helped to establish the Foundation in 1921. Robert B.Irwin, also blind, made many contributions to the field of the handicapped and while with the foundation, led the way for the final adoption of the present Standard English Braille. This was a compromise, settled in London (36,137) July 1932, between the British Revised Braille and the American grade one and a half.

Upon this card is found the print equivalent to the braille numerals and alphabet



The climb to the final international adoption of braille as the standard reading for the blind has been slow. Braille point has survived the many systems because of four chief advantages: it can be easily read and written by the blind and it can be most effectively adopted to music and mathematics (45,173)

Among others who contributed immeasurably were Pierre Villey, who wrote the invaluable book "The World of the Blind;" Dr. Howe Edward E. Allen; and such publishers as American Printing

House for the Blind, Louisville, under whose direction Director A. C. Ellis produces the brailled Reader's Digest; Howe Memorial Press, Boston; Matilda Ziegler Magazine, Monsey, New York; National Braille Press, Boston; London Daily Mail's weekly editions; National Institute for Blind of London; and the American Foundation for the Blind, New York City, of which Helga Lende is Librarian.

In 1920, a few schools for the blind used the dictaphone as a part of their educational program. George F. Myers, with his experiments in the late twenties, and Robert Irwin, with his research work in the early thirties, both blind andnow at the Foundation, led to the present Talking Book for the Blind (45,172). Rodenberg,however, believes that the Talking Book, valuable as it is, will not supplant braille in the classroom. Similarly, it is not expected that the braille slide rule will completely replace the slate or the geometry and trigonometry cushions.

Chapter III

Reading the Braille Slide Rule

The braille slide rule has for an object to provide a slide rule for use of the sightless or persons of defective vision. (See next page)

The study and practice of mathematical calculation presents particular difficulty when the worker is handicapped by impaired vision or total blindness and yet mathematics as a subject of study with the abstract reasoning required is of particular value in the education of the sightless.

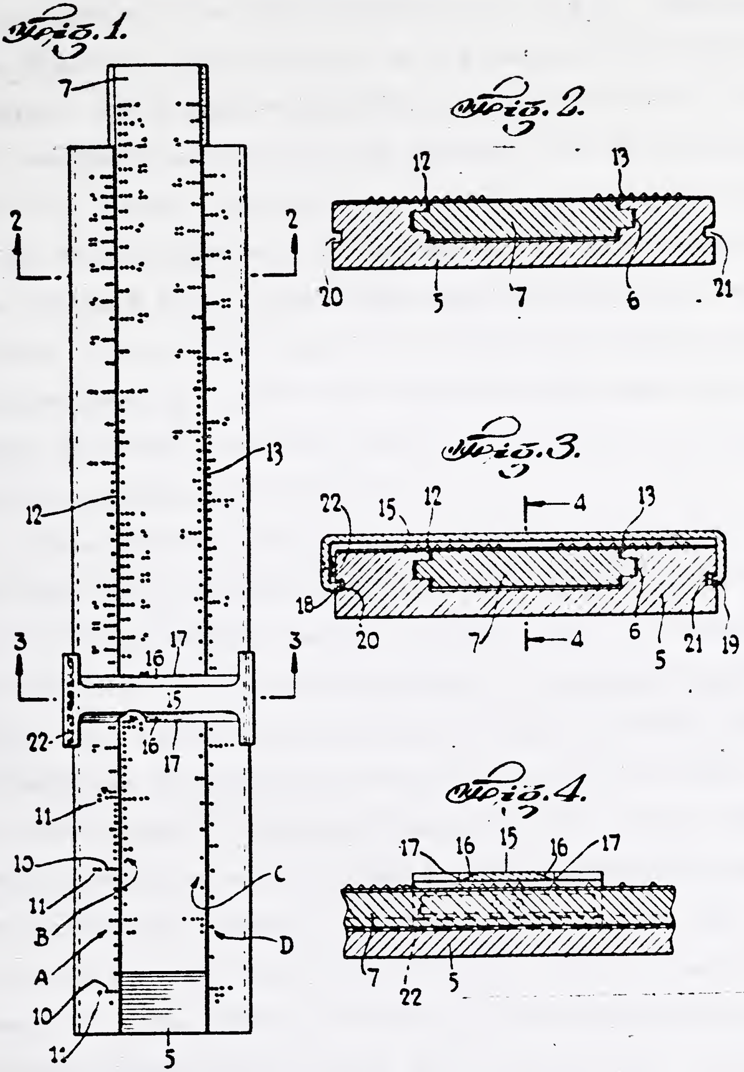
The braille slide rule is so constructed that it can be used by one depending entirely upon the sense of touch in manipulating and in reading the scales. All necessary lines are indicated by markings in relief, and in the preferred embodiment guide lines in relief are provided to avoid confusion between the markings on the different scales.

The nature and objects of the instrument will be better understood from a description of an illustrative embodiment for the purposes of which description reference should be had to the accompanying drawing forming a part of and in which -

Figure 1. is a plan view of a braille slide rule and ·

Figures 2,3 and 4 are sectional views taken, respectively, on the lines 2 - 2, 3 - 3, and 4 - 4 of Fig.1.

The slide rule shown for the purposes of illustrating the principles comprises a base 5 formed with a slide-way 6 to receive a slide 7. The base and slide carry the four scales A, B, C, D, as is usual in slide rules of a certain type. These scales are marked in relief whereby the blind person can read them by the sense of touch. The two adjacent scales A and B



THE BRAILLE SLIDE RULE

are similar. They are positioned along contiguous edges of the slide and base. Similarly, along two other contiguous edges are provided the two similar scales C and D. These scales as here shown are logarithmic as in the common slide rule. Also, the scales A and B provide two sets of numbers 1 to 10, or they may be considered as providing the numbers 1 to 100, whereas the scales C and D each provide one set of numbers 1 to 10. Furthermore, as in the common slide rule the scales A and D on the one hand, and the scales B and C on the other hand are positioned opposite each other to facilitate reading of squares and square roots. Lines corresponding to the logarithmically positioned numbers are indicated by properly selected dots or rows of dots in relief for convenient reading by the finger.

The most effective spacing of dots for reading by trained fingers has been determined from experience in the use of braille, and the braille standard spacing is adopted here. As indicated in Fig.1, the line positions corresponding to the primary numbers 1,2,3,etc. are indicated not only by the lines of three dots, as indicated at 10, but also by the dot or groups of dots, as at 11, which groups of dots are braille for 1,2, 3, etc. The intermediate positions between 1 and 2 and 3 corresponding to secondary numbers, for example, 1.1, 1.2, 1.3, 2.1, 2.2, etc., are each indicated by two dots with or without groups of dots which are braille for the numbers. Similarly, the intermediate tertiary numbers are represented by single dots with or without braille numbers. Special commonly used numbers may be added. For example, π is indicated on scales A and B by suitable dots.

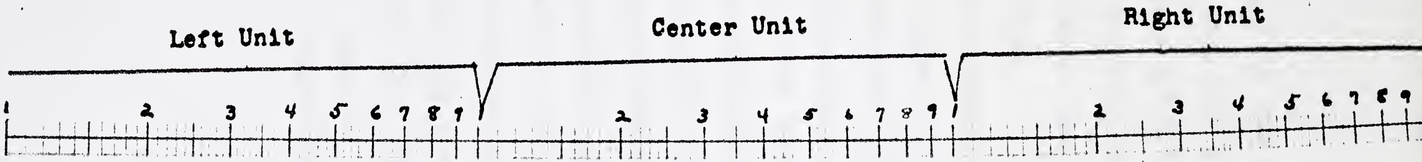
Obviously, if there is no provision for separating the scales, for example the C and D scales, there is always the pos-

sibility that in some position of the slide an inaccuracy in reading may occur. In order to avoid such misreading, a line of division detectable by touch is preferably provided between the A and B scales and between the C and D scales. In the preferred embodiment illustrated, the object is accomplished by providing ribs 12 and 13 which separate the respective scales. As shown, these ribs are formed on the base rather than on the slide.

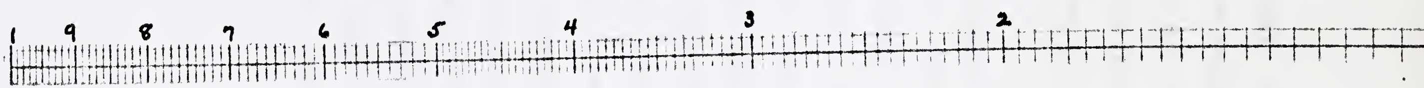
Accurate reading is facilitated by a slidable T-square or finger-guide 15 bevelled at 16 to provide transverse finger-guiding edges 17. Guide-tongues 18,19 slidably engage grooves 20, 21 in the base and maintain the finger-guide in position with the edges 17 above but close to the dot projections for convenient reading. By the use of the guide 15 not only are the adjacent scales easily read in correct correlation, but all four scales as well, as in the reading of squares and square roots. A spring 22 at one side of the slide applies a slight tension to hold the guide squarely against one side of the base and maintain it in correct position. The tongue 19 is preferably short, so that the finger-guide can be readily removed from the base by pressure applied to the opposite side to free the tongue 19 from its groove and then lifting the guide from the base.

Upon examination of the braille slide rule the student will find that it consists of three parts: the body, the slide, and the runner. Sometimes these three parts are called by other names. For instance, the body is referred to as the rule or ruler, the slide is sometimes called the slider, and the runner is often called the indicator or the cursor. (See Fig.1,page 18)

The body has scales lettered A D and K (not shown in Fig.1, but graphically represented here) while the slide has scales lettered B, CI (also not shown in Fig.1, but graphically represented here), and C.



The 3 unit K or Cube scale



The CI or Inverted scale

Except for the inverted CI scale, these scales read from left to right and are numbered in braille figures 1,2,3,4,5,6,7,8,9 and 10. This number 1 on the left end of the slide rule is known as the left index, and the number 1 on the right end, the right index.

These numbers, called primary or main numbers, decrease in space from left to right. This marking is unlike the foot rule which has equal spaces between its primary numbers. Between any two primary numbers on the D scale of the braille slide rule, the space is divided into the secondary parts which also decrease from left to right. Similarly, the space between two secondary numbers is divided into ten tertiary parts, as is clearly seen between the primary numbers 1 and 2. The space here is large enough to mark the smallest gradations, but the space between 9 and 1 is so small that the tertiary marks are not seen. Therefore, the student must always read, between 1 and 2, three figures and estimate the fourth figure in all his answers, and read be-

tween 2 and 9 inclusive, two figures and estimate the third figure in all his answers.

The scales C and D are identical and run the full length of the braille slide rule as one unit. A and B scales are identical but have two units of 1 to 10 for the full length of the braille slide rule. These units will be referred to as the left unit and the right unit. These two pairs of scales enable one to compute the squares and the square root of a number, locate 9 on the A scale. Placing the runner over it and following downward to the D scale, the answer 3 is found. To square 12 place runner over 12 on D scale and follow upward to A scale. Reading from left to right the answer is read 144. One (1) is at the index, fourth secondary figure to the right is the first 4. and the second tertiary mark to the right of it is the other 4 of the answer 144. On the left unit of the A and B scales (just to the right of the primary numberal 3) is found the Greek letter π , pronounced "pie." It is the constant ratio of the diameter and circumference of all circles and its value is 3.1416. Just to the left of the primary numberal 8 on the right unit of these scales, is found another special marking. This value is 0.7854 or one fourth π, or $\frac{1}{4}\pi$, or $\frac{\pi}{4}$. These two markings make the readings easier.

The CI or C-Inverse or reciprocal scale is equal in length to C and D scales. It is read from the right to the left index.

K scale, under D, reads from left to right, but has 3 units of 1 to 10 in the entire length of the braille slide rule. This scale facilitates computing of cubes and cube roots. Thus,

place the edge of the runner over 2 on the D scale. Follow downward to the K scale and read the answer 9. To cube 5 on the D scale, place the runner over 5 and read the answer 125 directly under it in the third unit of the K scale. This reading, 125, is also composed of a primary, secondary and tertiary number.

Accuracy in reading the braille slide rule is of prime importance, and this habit of accuracy should be achieved first. This achievement produces speed automatically. With training and practice on the braille slide rule, confidence in the instrument will be gained. Accuracy should not be sacrificed for the sake of speed in reading, for faulty reading soon brings about discouragement and loss of confidence in the instrument. The heart of all training and practice is in the reading of the scales correctly. Each line represents some number which is to be read accurately. The highest obtainable accuracy of the braille slide rule is roughly 1 part in 2000 and even with human error, this instrument offers a wide margin of safety for all practical purposes.

The scales of the braille slide rule are accurately engine-divided according to the logarithms of the numbers they represent. Since these scales are arranged in a geometric series, they decrease in distance as the numbers proceed to the right. If, then, two parts of these scales are added together, the sum of these parts represents the product of the number indicated by these parts. For example, if we add one part of the foot rule to another part of the foot rule, we shall obtain the sum of these parts because the foot rule is arranged in an arithmetical series of equal distances. If we add one part of the

braille slide rule to another part, we shall obtain the product because the braille slide rule is arranged in a geometrical series of decreasing distances as we proceed to the right. In using these scales, we must think only of figures with which we are dealing, not logarithms. This ease of handling is one of the great advantages of the braille slide rule.

Estimating beforehand, even before touching the braille slide rule, is another invaluable ~~to~~ step to be followed. A mental estimate of the outcome of each solution, of what the answer might be, of the position of the decimal point are necessary parts of a general forecast. Decimal points are never shown by the braille slide rule. Students must learn to estimate the position of the decimal point before the computation begins. Therefore, on reading 178, the figures may mean either 178000, 17800, 1780, 17.8, 1.78, 0.178, 0.0178, or 0.00178. The operator of the braille slide rule[7,957] must determine where the decimal point is placed in all his answers or follow his method for determination, or follow the suggested rules indicated later on..

First, place the left index 1 of C scale directly over the following numbers on the D scale.

Second, place the right index 1 of C scale directly over the given numbers on the D scale.

Third, place the edge of the runner, either left or right, over the following numbers on the CI scale. The purpose of the runner is to transfer reading from one scale to another scale as further work will indicate.

2	43	40	1.05	40.50
4	46	2.5	3.22	0.004
5	68	1.7	10.5	0.185
7	29	8.1	11.5	1198
3	14	3.2	10.1	2241
8	30	1.4	1.45	2040
15	84	7.6	0.002	1059
21	91	5.8	4.15	1865
11	53	9.4	9.05	4950
35	79	4.7	3.02	11.550

Chapter IV.

Its Care and Manipulation

To care for an instrument like the braille slide rule, one need not exercise any caution beyond good common sense. One danger which might render less efficient use of it would be to get the instrument wet. This would permit swelling of the wood which in turn would prevent easy sliding of the pieces. Then, too, laying the instrument near excessive heat, as for instance, near a radiator will affect its best use. Dropping, hitting, bending of the instrument will deface, scar or warp it. Talcuming sticky areas is sometimes employed, but this is not advised; while sandpapering or planing should never be employed. Sometimes high humidity might cause stickiness; if so, it is likely to pass away when the humidity recedes. The braille slide rule is made of excellent materials with skilled craftsmanship, machined markings, and engineered to perfection. With reasonable good care, the instrument should last indefinitely.

The manipulation of the slide rule is best done with the full use of both hands. It is an excellent opportunity to use many fingers. Students with but little practice employ one or more of four fingers in reading, the second and third fingers of both hands. The third and fourth fingers are also used to push the slide along to the desired position by placing the plush of these fingers on the face of the slide. The little fingers can be used by pressing on the very end of the slide to adjust it for reading. The thumb or thumbs are usually found to be employed on the vertical side of the body to steady the fingers, the runner, or the slide. In consideration of the fact that the braille slide rule is divided

into ten parts and tenths thereafter, it is excellent practice to train the fingers in judging and measuring tenths of any unit.

Marking facilitates the finding of the midpoint between two primary numbers on the D scale. Then searching for the four marks between the primary number and midpoint, allowing for the slight decrease in space toward the right, is one of the best practice methods. Finally, judging and measuring the remaining four tenths, their midpoints, and their subsequent four tenths are first requisites to becoming a reader of the braille slide rule.

Chapter V.

Multiplication

Using the C and D Scales

Place the left index of the C scale to 3 on the D Scale. Each number on the D scale is 3 times the number above it on the C scale. If the right index of the C scale is placed to 7 on the D scale, each number on the D scale will be 8 times the number above on the C scale.

Place an index at the C scale over one factor on the D scale in multimplication; then under the other factor on the C scale, find the answer on the D scale. Again, place the left index of the C scale over 17 in the problem, 17 x 45. Then under 45 on the C scale, find the product on the D scale, 765. Note the illustration below.

	C	Left index 1	The other factor
X			
	D	One factor	Answer

X indicates that it is a problem in multiplication.
C and D are the scales used
Index 1 of C scale over one factor on D scale and under the other factor the answer is found.

It does not matter whether you place the left index 1 over the multiplacand or the multiplier, for your product will be the same. Place left index 1 over 17 on the D scale and under 45 on the C scale, find 765 on the D scale. Now place the left index 1 over 45 on the D scale, and under 17 on the C scale, find 765 on the D scale.

To determine which index to use, right or left, the following suggestion will help. In considering the same

problem 17 X 45, if the product of the first digit of each of the two factors is less than 10, use the left index. One (1) is the first digit of 17 while 4 is the first digit of 45. The product, 1 X 4 = 4, is less than 10. Therefore, use the left index. If the product of these digits is greater than 10, use the right index. In the problem 84 X 43, the product of 8 X 4 = 12 is greater than 10. Therefore, use the right index. Exceptions to the previous suggestion are found in such problems as 18 X 57, 23 X 49, 36 X 34, in which the second digits are so large they carry the product above ten. In such cases, the right index is to be applied. However, by inspection and with some practice, a student soon becomes adept at this.

Decimals The technique to determine the place of the decimal point is the method which has already been learned by the student. This method should be first because it can be applied to the braille slide rule. An invaluable practice for the student is to estimate where the decimal point will be placed before he picks up the braille slide rule for computation. In most problems, the location of the decimal point is determined by an estimate. The following suggestions may aid a beginner in making such estimates.

Left Index. When the left index is used, or the slide projects to the right, in multiplication, the product will have as many places as the sum of the digits in the multiplier and the multiplicand, minus one.

17 X 45 = 765, 17 had 2 digits, 45 has 2 digits

2 + 2 = 4. Since the left index is used, or the slide goes to the right, 1 is taken from the total number of digits of 4. 4 - 1 = 3. There are 3 digits in the product. The steps are, briefly, the sum, to the right, minus one. Note the illustration below:

X			
	C	1	45
	D	17	765

Right Index. When the right index is used, or the slide projects to the left, the product will have as many places as the sum of the digits of the multiplier and the multiplicand.

60 X 42 = 2520. 60 has 2 digits. 42 has 2 digits. 2 + 2 = 4. Since the right index is used, or the slide goes to the left, the product will have 4 digits for an answer. The steps are, to the left, the sum. Note the illustration below.

X			
	C	42	1
	D	2520	60

When digits are counted to the right of the decimal point, only the zeros between the decimal and the first significant figure are counted. Each zero is counted as minus one. 0.081 has one zero between the decimal point and 8. Therefore, one digit is taken negatively, minus one digit.

2410	has 4 digits
842	has 3 digits
23	has 2 digits
6.5	has 1 digit
0.54	has 0 digits
0.0075	has -2 digits
0.00045	has -3 digits

21 X 0.7 = 14.7 21 has 2 digits. 0.7 has 0 digits, 2+ 0 = 2. Since the slide projects to the left, there are 2 digits in the product or answer. Note the illustration below.

X	C	7	1	
	D	147	21	

15 X0.05 = 75. 15 has 2 digits. 0.05 has -1 digit. 2+ (-1) =1 Since the slide projects to the right, one is subtracted from the sum of the digits. 1-1 = 0 The answer has 0 digits. There are no zeros between the decimal point and the first significant figure; hterefore, the decimal point is placed in front of the first figure.

X	C	1	0.05
	D	15	0.75

0.007 X 0.025 = 0.000 175. 0.007 has -2 digits. 0.025 has - 1 digit. The slide projects to the left, (-2) + (-1) = - 3. The answer will have -3 digits.

X	C	0.025	1
	D	0.000175	0.007

Three factors. In multiplying three factors, 2 X 3 X 4 = 24, place the left index 1 over 2 on D scale. Under 3 on the C scale is the product of 2 X 3, on the D scale. Place the runner on the product and then move the right index 1 over this product. Now under 4 on the C scale, read the answer,

There are 4 steps to follow

1. Left index over first factor
2. Runner over both second factor and product.
3. Right index over product
4. Answer under third factor

x	C	Left Index	3
	D	2	Product

then,

x	C	3	Right Index
	D	24	Product

Exercides 1.

Multiplication on the C and D Scales

1. 2 X 2
2. 2 X 3
3. 4 X 2
4. 2 X 2.5
5. 3 X 1.4
6. 2 X 1.9
7. 16 X 16
8. 14 X 60
9. 18 X 18
10. 56 X 15
11. 22 X 14
12. 24 X 20
13. 17 X 25
14. 21 X 19
15. 11.4 X 3.07
16. 1.75 X 4.13
17. 3.38 X 1.036
18. 1.27 X 6.52
19. 2.1 X 4.07
20. 4.3 X 1.08
21. 3.45 X 2.46
22. 2.71 X 1.24
23. 3.06 X 30.6
24. 2.01 X 1.09
25. 11.3 X 3.1
26. 4 X 4
27. 3 X 4
28. 6 X 5
29. 6 X 6
30. 2 X 88
31. 8 X 7
32. 9 X 92
33. 24 X 47
34. 53 X 36
35. 79 X 43
36. 84 X 74
37. 19 X 91
38. 45 X 75
39. 51 X 29
40. 36 X 60
41. 7.04 X 3.02
42. 2.75 X 6.44
43. 2.04 X 5.82
44. 4.26 X 6.83
45. 7.36 X 87.3
46. 5.09 X 2.83
47. 8.32 X 4.26
48. 5.75 X 7.84
49. 37.5 X 6.27
50. 8.75 X 2.86

51. 0.00113 X 42

52. 4.05 X 4.2

53. 0.000845 X 0.036

54. 0.0011 X 79

55. 9.8 X 0.75

56. 0.684 X 0.199

57. 8.6 X 0.474

58. 6.06 X 0.009

59. 0.778 X 144

60. 0.885 X 121

61. 4 X 3 X 9

62. 11 X 35 X 4

63. 9 X 2 X 28

64. 1. 5 X 0.34 X 7

65. 3.15 X 0.75 X 0.04

66. 75 X 2.3 X 8.4

67. 0.0043 X 0.051 X 144

68. 109 X 1.09 X 0.109

69. 4.75 X 0.00755 X 0.381

70. 0.077 X 411 X 2.5

71. 840 X 7.15 X 0.09

72. 14 X 0.8 X 3.14

73. 6.2 X 72 X 0.119

74. 7.4 X 3.14 X 3.14

75. 0.157 X 0.62 X 0.00082

Using the CI and D scales

The CI and D scales are best for multiplications generally. Although multiplications may be done on other pairs of scales, students soon find this pair is most useful. Since one factor is placed over the other factor, it eliminates the need for selecting the index to be used. The products are found under the index.

CI scale is the same as the C and D scales only it is inverted, namely, CI. It reads from right to left index. Beginners must learn to read it in this way. Generally, on the D scale, place the runner over one factor and under the runner on the CI scale, place the other factor. Now, by moving the runner to the index on the CI scale, read the answer on D scale. Thus

X	CI	One Factor	Index
	D	The Other Factor	Answer

Decimal Point. The fact that CI is the reverse of C and D makes it easy for the student to remember to reverse the rule for C and D decimal point position. If the slide extends to the right, the product will have as many digits as the sum of the digits in the multiplicand and the multiplier.

If the slide extends to the left, the product will have as many places as the sum of the digits in the multiplicand and the multiplier, minus one.

Thus, 2 X 64 = 128

X	CI	1	64
	D	128	2

The sum of the digits of both multiplicand and the multiplier is three. Therefore the answer will have three places.

Thus, 0.041 X 0.0012 = 0.0000492

X	CI	0.0012	1
	D	0.041	0.0000492

The sum of the digits of both multiplicand and the multiplier is -3. Since the slide extends to the left, another minus one must be added. -3+ (-1) = -4. There are 4 zeros between the decimal point and the answer 492.

Exercise 2.

Multiplication on the C I and D Scales

1. 5 X 4
2. 7 X 6
3. 3 X 9 X 3
4. 27 X 9 X 14
5. 64 X 48 X 34 X 4
6. 46.9 X 37.4
7. 0.0987 X 0.973
8. 9.7 X 7.4 X 3.45
9. 5.86 X 38 X 0.97
10. 35.9 X 0.098
11. 56.9 X 0.0047
12. 12 X 72 X 39
13. 0.369 X 84
14. 0.97 x 38 x 34
15. 53 X 0.53 X 0.053
16. 144 X 0.97 X 88
17. 8.5 X 3.4 X 0.09
18. 9.5 X 8.6 X 0.43
19. 8.2 X 7.5 X 3.9
20. 0.54 X 0.94 X 0.094
21. 0.0057 X 43 X 54
22. 45 X 0.034 X 82
23. 35.4 X 1.7 X 2.3
24. 150 X 7.3 X 4.5
25. 27.4 X 4.83 X 0.956
26. 4.34 X 56.3 X 0.128
27. 2450 X 0.0963 X 0.0458
28. 3.78 X 1.83 X 0.0243
29. 7.23 X 0.0738 X 57.6
30. 0.0584 X 0.483 X 0.175
31. 2150 X 0.567 X 0.0345
32. 10.8 X 0.458 X 6.37
33. 957 X 0.0593 X 0.0637
34. 5.43 X 1.87 X 723
35. 1.75 C 67.5 X 6.34
36. 7.25 X 4.48 X 5.93
37. 3.75 X 4.83 X 8.34
38. 125 C 0.00375 X 0.95
39. 0.0964 X 8.36 X 0.0138
40. 0.125 X 0.0125 X 0.00125
41. 34.3 X 43.4 X 5.25
42. 0.012 X 0.314 X 125
43. 3.14 X 0.785 X 0.5 X 8
44. 8.94 X 0.96 X 7 X 0.35
45. 2 x 5 x 9 x 91
46. 3.46 X 7.5 X 9.7 x 0.05
47. 73 X 48 X 5 X 23
48. 48 X 4 X 68 X 34
49. 9.05 X 0.36 X 881 X8
50. 89 X 8.5 X 44 X 2.77

Using the A and B Scales

The two units, left and right, on each of these scales, have three indices: left index, center index and the right index. Multiplication may be done upon each unit, but it is better to confine all work upon one unit, at first. Although the work on C, Cl and D scales is easier and more accurate, the work on the A and B scales is necessary to obtain the squares and square roots and to obtain the full use of the two special markings, π and $\frac{1}{4}\pi$. To multiply on the A and B scales, place the index of B under one factor of the A scale and read the answer on A scale over the other factor on the B scale.

X	A	One factor	Answer
	B	1	Other factor

Decimal Point. Either by an estimation of the position of the decimal point or the following suggested principle of projecting slides may be used to determine the position of the point. If the slide projects to the right, the product will have as many places as is the sum of the digits of both factors minus one. If the slide projects to the left, it is the sum of both the factors. The above principle is reversed when the center index is passed in computations.

Example, 34 X 50 = 1700

X	A	1700 answer	34
	B	50	1

There are four places in the answer, for the slide projects to the left which calls for the sum of the digits

of both factors. The center index was not passed.

Example, 14 X 25 = 350.

X	A	14	350 answer
	B	1	25

Since the slide projects to the right, the sum of the digits of both factors minus one, 4-1=3, and the answer will have three places. Again, the center index was not passed.

Example, 28 X 50 = 1400

X	A	28	1400 answer
	B	1	50

The answer 1400 and 50 have passed the center index. Therefore the rule is reversed. The sum of the digits of both factors is 4 and since the slide projects to the right, the sum only is required. There are 4 places in the answer.

Exercise 3.

Multiplication, Using the A and B Scales

1. 16 X 25
2. 3.1416 X 3
3. 6 X 3.1416
4. 3.1416 X 3.146
5. 11 X 0.7854
6. 6.5 X 0.06
7. 0.40 X 17
8. 8.6 X 0.04
9. 15 X 75
10. 81 X 3.1416
11. 0.031 X 46
12. 3.1416 X 0.7854
13. 11.4 X 86
14. 0.7854 X 0.7854
15. 27 X 8 X 5
16. 47 X 20 X 15
17. 2.4 X 71 X 0.51
18. 11.4 X 0.55 X 0.64
19. 0.14 X 0.015 X 6
20. 43 X 0.7854 X 0.012
21. 13 X 15 X 4
22. 21 X 3.1416 X 40
23. 0.7854 X 0.41 X 1.5
24. 20 X 0.7854 X 20
25. 1.56 X 3.1416 X 0.24

REVIEW

1. Multimplication on

A	One factor	Answer
B	Index	The other Factor

Decimal Point. Projecting to the left, sum of the digits.
Projecting to the right, sum of the digits minus one.
Reverse the process if center index is passed.

2. Multiplication on

C	The Other Factor	Index
D	Answer	One Factor

Decimal Point. Projecting to the left, sum of the digits.
Projecting to the right, sum of the digits minus one.

3. Multiplication on

CI	Index	One Factor
D	Answer	The Other Factor

Decimal Point. Projecting to the left, sum of the digits minus one.
Projecting to the right, sum of the digits.

Chapter VI.

Division

Using the C and D Scales. To divide, place the dividend on the D scale and over it place the divisor. Under the index read the quotient. Thus,

÷	C	Index	Divisor
	D	Answer	Dividend

The position of the decimal point can be estimated easily in most problems or the following suggestions may be applied. Since division is the reverse of multiplication, the reverse of the decimal point suggestions are applied. If the slide extends to the left, the quotient will have as many places as the difference of the digits of the dividend and the divisor. If the slide extends to the right, the quotient will have as many places as the difference of the digits of the dividend plus one. The zeros, between the decimal point and the first figure in decimal fractions, are again taken negatively.

Example: $125 \div 5 = 25$

÷	C	5	1
	D	125	25 answer

Since the slide extends to the left, the quotient will have two places. 125 has three digits while 5 has 1 digit, $3 - 1 = 2$.

Example, $144 \div 12 = 12$

÷	C	1	12
	D	12 answer	144

Place the runner over 144 on D and under the runner, set 12 of the C scale. Since the slide extends to the right, the quotient will have as many places as the difference between the digits of 144 and 12 plus one, 3 - 2 + 1 = 2.

Example: 48 ÷ 0.03 = 16

÷			
	C	1	3
	D	16 answer	48

Under the runner, place 48 on the D scale. Place 3 on the C scale to 48. Under the index the quotient is 16, or 1600 with decimal 48 has 2 digits while 0.03 has -1 digit. Since the slide extends to the right, one is added, 2 - (-1) + 1 = 4 The answer, 1600, has four places.

Exercise 4.

Division of the C and D Scales

1. 35 ÷ 5
2. 88 ÷ 11
3. 750 ÷ 30
4. 24.5 ÷ 7
5. 11.25 ÷ 1.25
6. 36.4 ÷ 0.42
7. 87.5 ÷ 0.15
8. 3.1416 ÷ 0.7854
9. 386 ÷ 29
10. 466 ÷ 17
11. 182 ÷ 0.62
12. 1725 ÷ 46
13. 0.648 ÷ 0.0012
14. 0.725 ÷ 0.55
15. 77 ÷ 30.5
16. 1.75 ÷ 4.2
17. 742 ÷ 37.5
18. 386 ÷ 144
19. 96 ÷ 45.5
20. 844 ÷ 0.16
21. 0.7854 ÷ 3.1416
22. 128 ÷ 0.96
23. 0.072 ÷ 0.74
24. 0.0049 ÷ 0.0023
25. 0.00062 ÷ 0.005

<u>Using the CI and D Scales.</u> Over the dividend on D, place an index of Ci and under the divisor on CI, find the quotient on D. Again, the decimal point position can be estimated easily or the suggested rule may be applied. If the slide extends to the left, take the difference between the digits of the dividend and divisor and add one. If the slide extends to the right, the difference between the digits of the dividends and the divisor will be the number of places in the answer.

Example: 54 ÷ 3 = 18

÷			
	CI	3	I
	D	18 anser	54

Since the difference between the number of digits in the dividend and divisor is one, and one is added for the extension of the slide to the left, and quotient will have two places: 2 - 1 + 1 = 2.

Example: 28 ÷ 7 = 4

÷			
	CI	I	7
	D	28	4

The slide projects to the right. The difference between the number of digits in the dividend and the divisor is one. The answer has one figure.

Exercise 5.

Division on the CI and D Scales

1. 24 ÷ 3
2. 48 ÷ 8
3. 54 ÷ 6
4. 144 ÷ 8
5. 275 ÷ 15
6. 344 ÷ 40
7. 876 ÷ 542
8. 43.5 ÷ 2.4
9. 1.78 ÷ 0.31
10. 0.86 ÷ 0.013
11. 0.092 ÷ 0.008
12. 7.6 ÷ 0.04
13. 8.05 ÷ 3.5
14. 0.1725 ÷ 0.063
15. 4.35 ÷ 2.2
16. 3.06 ÷ 0.18
17. 8.6 ÷ 2.02
18. 66 ÷ 4.9
19. 393 ÷ 120
20. 1158 ÷ 712
21. 840 ÷ 0.60
22. 742 ÷ 18.1
23. 1255 ÷ 15
24. 945 ÷ 8.05
25. 860 ÷ 340

Using the A and B Scales. Division is sometimes necessary when making other computations on the A and B scales. To divide on these scales, place the runner on the dividend on the A scale and under it, set the divisor on the B scale. Over the index of B, read the quotient on A.

Since the center index is frequently passed, the reverse of the following suggestions for the position of the decimal point is applied if the position is not estimated mentally. If the slide extends to the left, the quotient will have as many places as the difference between the number of places in the dividend and the divisor. If the slide extends to the right, one is added to the difference between the number of digits in the dividend and the divisor to determine the number of places in the quotient. The zeros in decimal fractions between the decimal point and the first figure are taken negatively.

Example: 28' ÷ 7 = 4

÷	A	28	4 answer
	B	7	1

The difference between the number of the digits in the dividend and the divisor is one. Since the slide extends to left, the quotient will have one digit.

Example: 68 ÷ 4 = 17

÷	A	17 answer	68
	B	1	4

Since the slide extends to the right, one is added to the difference, giving the quotient two places.

Exercise 6.

Division on the A and B Scales

1. $16 \div 4$
2. $18 \div 6$
3. $36 \div 9$
4. $88 \div 44$
5. $120 \div 15$
6. $1600 \div 25$
7. $38 \div 16$
8. $86 \div 43$
9. $121 \div 17$
10. $3.1416 \div 3$
11. $12 \div 3.1416$
12. $0.7854 \div 2$
13. $66 \div 0.032$
14. $98 \div 11.5$
15. $2.05 \div 0.036$
16. $44.5 \div 3.6$
17. $7650 \div 312$
18. $485 \div 205$
19. $3.1416 \div 0.7854$
20. $8.6 \div 3.1416$
21. $11.25 \div 8.2$
22. $3.1416 \div 4.5$
23. $6.05 \div 0.12$
24. $0.0048 \div 0.06$
25. $0.035 \div 0.0075$

REVIEW

Division on

A	Dividend	Answer
B	Division	Index

Decimal Point. Projecting to the left, difference of the digits.

Projecting to the right, difference of digits add one.

Reverse the process if the Center Index is passed.

Division on

C	Division	Index
D	Dividend	Answer

Decimal Point. Projecting to the left, difference of digits.

Projecting to the right, difference of digits add one.

Division on

CI	Index	Divisor
D	Dividend	Answer

Decimal Point. Projecting to the left, difference of the digits add one.

Projecting to the right, difference of the digits.

Chapter VII.

Combined Multiplication and Division

The combined operations of multiplication and division should be confined to the C, D, and CI scales. These scales offer greater accuracy than the smaller scales, A and B. Either an estimation beforehand or the rules for the projecting slide may be used to determine the position of the decimal point in the combined operations. Ordinarily, problems of multiplication and division require more than one setting. Frequently, the problem may be solved in perhaps two or three ways. When this is true, accuracy and the least amount of movement of slide and runner prove the best guides for efficiency.

Example: $\frac{2 \times 9}{3} = 6$

Combined:

X and ÷

C	Multiplier	Divisor
D	Answer	Multiplicand

of

Combined:

X and ÷

C	2	3
D	6 answer	9

Example: $\frac{40}{2 \times 8} = 2.5$

Combined:

X and ÷

CI	8	
C		2

Divide 40 by 2 on the C and D scales. Then divide this quotient, under the index of C, which need not be read, by 8 of the CI scale. Under the 8, with the aid of the runner, the final quotient, 2.5 is found on the D scale.

The decimal point may be estimated easily. Since $40 \div 16$ is a little over 2, the answer will approach that rough estimate.

Example: $\frac{5.85 \times 3.92 \times 9.45}{5.65 \times 8.25} = 4.65$

In solving this problem, the following pattern is usually employed: divide 5.85 by 5.65, multiply the result by 3.92, divide this second result by 8.25, and multiply this third result by 9.45. Thus, in two settings:

X and ÷			
	C	392	565
	D	Result	585

X and ÷			
	C	825	945
	D		465 answer

In the first setting, place the runner to 585 on D, and under the runner, set 656 on C. The result of this operation is found under 392 on C. To this result, set the runner, and under the runner, place 825 on C. Under 945 on C, read 465 on D, the final result.

The position of the decimal point is estimated roughly in the answer, 465, in this manner: $\frac{6 \times 4 \times 9}{6 \times 9} = 4.$ Thus, the final result must have one digit and approach 4. 4.65 answer.

Combined Multiplication and Division

1. $\dfrac{8\ 4}{6 \times 7}$

2. $\dfrac{144}{2 \times 3}$

3. $\dfrac{3 \times 5 \times 6}{3 \times 4}$

4. $\dfrac{24 \times 6 \times 0.12}{0.42 \times 11.2}$

5. $\dfrac{2.82 \times 4 \times 6.2}{4 \times 0.5 \times 6}$

6. $\dfrac{18 \times 8}{6}$

7. $\dfrac{450 \times 12}{150}$

8. $\dfrac{95 \times 60 \times 36}{75 \times 13}$

9. $\dfrac{2.15 \times 1.25 \times 8.4}{1.65 \times 44 \times 0.06}$

10. $\dfrac{8 \times 0.55 \times 120}{4.5 \times 6 \times 16}$

11. $\dfrac{125 \times 6 \times 4}{1.1 \times 6.2 \times 40}$

12. $\dfrac{3.1416 \times 0.7854 \times 144}{0.62 \times 85 \times 16.5}$

13. $\dfrac{3 \times 3.1416 \times 5}{0.7854 \times 1.57 \times 6}$

14. $\dfrac{144 \times 3.06 \times 22}{3.1416 \times 12.5 \times 11}$

15. $\dfrac{184 \times 125 \times 0.06}{0.008 \times 32 \times 115}$

Chapter VIII.

Figuring Costs

The figuring of costs, discount, sales tax, unit price, representing problems of multiplication or division, are conveniently solved upon the C and D scales. The position of the decimal point is estimated, easily, or the method of the projecting slides may also be applied.

Example: What is the total cost of labor if 5 men each work a total of 420 hours at 80 cents an hour?

Cost	C	80	1
	D	Product	420

Cost	C	5	1
	D	168 Answer	Product

In the first setting, place the index of C over 420 on D; the first product is under 80. In the second setting, place the index of C over the product and under 5 of C, read the final result, 168. Either by inspection or the rule of projecting slides, the position of the decimal point reveals 4 places in the answer, $1680.

Exercise 8.

1. What is the cost of shipping a box, weighing 105 pounds, a distance of 425 miles at $3\frac{1}{2}$ cents a pound?
2. If 1000 brick cost $22.00, what is the cost of 8250 brick?
3. If nails cost $8\frac{3}{4}$ cents a pound, how many pounds can you buy for $14.75?
4. If the cost of operating a steam shovel with its crew to excavate 82 cubic yards is $520.00, what is the cost for one cubic yard?
5. If a building with a capacity of 39,000 cubic feet costs $6,750.00 to construct, what would be the cost of a building with a capacity of 5,000 cubic feet?
6. If 824 feet of fence cost $165.00, what does one foot cost?
7. If a gallon of gasoline costs $21\frac{1}{2}$¢, what is the cost of 18 gallons?
8. If fuel oil costs $3\frac{1}{4}$¢ a gallon, what is the cost of 425 gallons?
9. If lumber costs $42.00 a thousand feet, what is the cost of 6500 feet?
10. A man bought 3 cows at $420.00; at the same rate, what would he pay for 21 cows?

Chapter IX

Ratio and Proportion

The ratio of two numbers 3 and 4 is the quotient of 3 divided by 4. Whereas, proportion is a relation of equality between two ratios, or couplets of numbers.

Thus: $3:4 = 9:12$, or $3/4 = 9/12$

$X:5 = 4:10$, or $X/5 = 4/10$

By placing these numbers into couplets or pairs, one small number is to a large number as another small number is to another large number, or by reversing these pairs, the position of the decimal point can be determined more readily by estimation.

The C and D scales should be used for ratio and proportion. The ratio of any couplet on the D scale to its opposite on the C scale is the same as the ratio of any other couplet on the D scale to its opposite on the C scale.

Example, solve for X in, $22:14 = 55:X$

Proportion			
	C	22	55
	D	14	35 answer

Since 14 is a little over one half of 22, the answer will be approximately a little over one half of 55.

Example, solve for X in, $18:X = 63:189$

Proportion			
	C	18	63
	D	54 answer	189

Since 189 appears to be about three times greater, by inspection, than 63, the answer will be about three times greater than 18. Remember, the large numbers are on the

C scale when the small numbers will be on the D scale.

Reversing the small to the C scale and the large numbers to D scale is seen too, as was done in the last example.

Example, solve for the value of X,Y & Z in,

$$\frac{2.8}{5.1} = \frac{X}{4.55} = \frac{3.16}{Y} = \frac{Z}{765}$$

Proportion

C	2.8	X	3.16	Z
D	5.1	4.55	Y	765

The above problem is solved by one setting. The known ratio or couplet 2.8/5.1 is set upon C and D scales respectively. Place the runner to 455 on D and read X= 25 on C; opposite 316 on C, read Y = 575 on D; opposite 765 on D, read X = 420.

Thus, supplying values for X, Y, and Z.

Propostion

C	2.8	X = 25	3.16	Z = 420
D	5.1	4.55	Y = 5.75	765

Decimal points will be~~t~~ determined by noticing that the numerators are approximately one half of the denominators throughout.

Exercise 9.

Ratio and Proportion using the C & D Scales

Solve, in each of the equations, the values of the unknowns.

1. 6 : 8 = 3 : X
2. 8 : 10 = 11 : X
3. 12 : 15 = 7 : X
4. 8 : 12 = X : 28
5. 9 : 15 = X : 64
6. 24 : 36 = X : 90
7. 18 : X = 9 : 12
8. 48 : X = 64 : 16
9. X : 7 = 56 : 49
10. X : 5 = 90 : 45
11. 2 : 6 = 3 : X
12. 5 : 2 + 8 : X
13. 12 : 16 + X : 80
14. 125 : 375 = X : 90
15. 43 : X = 21 : 52. 5
16. 16: X = 1.2 : 4.8
17. X : 5 = 3.7 : 18.5
18. X : 3.1416 = 4 : 2.1
19. 2/3 = 10/X
20. 5/8 = 40/ X
21. 4/7 = X/98
22. X/25 = 32/100
23. $\frac{2.5}{4.5} = 2/X$
24. $\frac{3.1416}{X} = \frac{46}{69.5}$
25. $\frac{0.7854}{X} = \frac{95}{145}$

Chapter X.

Powers and Roots

Squares. The square of a number is the result of multiplying the number by itself, as in $3 \times 3 = 9$, or $3^2 = 9$. The braille slide rule has a very advantageous characteristic here: pull out the slide entirely. Set the runner at any place on the rule, the reading on A scale is just the square of that on D. Now the reading under the runner on D is just the square root of that on A. For example, place the runner on 15 on D and read the answer 225 on A. The square root of 225 is 15. Nothing is more simple than these calculations. By inserting the slide, the B and C scales can be used exactly as the A and D scales with the runner. Also, with the indices in true line, the A and C scales may be used and the B and D scales may be used for the squares and square roots.

Decimal Points. The A and B scales have two units of 1.0 to 10.0 for one length of the braille slide rule. This provides three indices, left index, center index and the right index. A square falling to the left of the center index, or in the left unit of A, has as many figures in the answer as twice the number of digits, minus one, of the number to be squared on D. Thus in $12^2 = 144$, 12 has two digits, multiplied by two, minus one, we have $2 \times 2 - 1 = 3$, three figures in the answer.

A square falling to the right of the center index, or in the right unit of A, has twice the number of digits in the number to be squared on D. The square of 50 is 2500. 50 has two digits. Twice the number of digits is four, the number of digits found in the answer.

In decimal fractions, the square falling to the left of the center index on A has twice the number of zeros, plus one, between decimal point and the first significant figure of the number on D. The square of 0.003 is 0.000009. The number of zeros between the decimal point and the first figure is 2. Twice this number is four and one added is 5. There are 5 zeros between the decimal point and the first significant figure.

In decimal fractions, the square falling to the right of the center index on A has twice as many zeros between the decimal point and the first significant figure of the number on D. The square of 0.05 is 0.0025. There is one zero in the decimal fraction to be squared. Twice this number is two, the number of zeros to be placed between the decimal point and the first figure of the square.

Combining Squares with Multiplication and Division

Example, $3 \times 5^2 = 75$

	A	75	Square
X	B	3	1
	D		5

Place the runner over 5 on D. The square is on A. Set the B index to this square and over 3 find the answer. Either estimate the position of the decimal point or use the suggested method of projecting slides.

Example, $2^2 \times 4^2 = 64$.

	A		64, Answer
X	C	1	4
	D	2	

Multiply 2 X 4 on the C and D scales. Read the answer on A Scale.

Example, $15^2 \div 5 = 45$.

	A	Square	45, answer
÷	B	5	1
	D	15	

Place 15 on the D scale and on A find the square. Using this square as a dividend, place 5 of the B scale, as a divisor, under this dividend. Read the quotient, the answer over the index of the B scale.

Example, $48 \div 2^2 = 12$

	A	12, answer	48
÷	B	1	
	C		2

Place the runner to 48 on the A scale. Place 2 of the C scale to the runner. Over the index of the B scale read the answer on the A scale.

Example, $6^2 \div 3^2 = 4$

	A	4 answer	
$\div$	C	1	3
	D		6

Divide 6 by 3 on the C and D scales and read the answer on the A scale over the index of the C scale.

Exercise 10.

Find the value of

1. 23^2
2. 19^2
3. 49^2
4. 0.12^2
5. 0.05^2
6. 0.7854^2
7. 0.004^2
8. $5^2 \times 7$
9. $24^2 \times 0.6$
10. $3.14^2 \times 4$
11. $8^2 \times 0.08$
12. $0.07^2 \times 5$
13. $84^2 \times 3$
14. $33^2 \times 0.5$
15. $0.07^2 \times 9$
16. $72^2 \times 0.03$
17. $44^2 \times 0.004$
18. $5^2 \times 20$
19. $30^2 \times 8.5$
20. $11.5^2 \times 0.02$
21. $50^2 \times .314$
22. $0.75^2 \times 40$
23. $0.84^2 \times 0.6$
24. $14^2 \times 4 \times 5$
25. $11^2 \times 3 \times 21$
26. $6^2 \div 2$
27. $65^2 \div 5$
28. $144^2 \div 10$
29. $57^2 \div 36$
30. $84^2 \div 10.5$
31. $3.5^2 \div 20$
32. $60^2 \div 90$
33. $6.5^2 \div 0.03$
34. $240^2 \div 732$
35. $300^2 \div 4.5$
36. $785^2 \div 3.14$
37. $0.785^2 \div 5.1$
38. $9^2 \div 3^2$
39. $12^2 \div 5^2$
40. $20^2 \div 10^2$
41. $45^2 \div 20^2$
42. $60^2 \div 0.06^2$
43. $50^2 \div 0.5^2$
44. $27^2 \div 31^2$
45. $61^2 \div 11.5^2$
46. $314^2 \div 0.55^2$
47. $18^2 \div 4^2$
48. $125^2 \div 0.05^2$
49. $64^2 \div 3.14^2$
50. $800^2 \div 40^2$

Square Root. To extract the square root of a number on the braille slide rule, the given number is found on the A scale and its square root is found directly below it on the D scale by means of the runner.

The left unit of the A scale is used, left of the center index, when the number has an odd number 1,3,5,7, of digits. In extracting the square root of a number which has an even number of digits, 2,4,6,8, the right unit of A scale is employed. If the given number is a whole number with a decimal fraction. The whole number determines the unit of A scale to be used.

In decimal fractions, the number of zeros between the point and first figure determine which unit is to be used. Odd number of zeros go to the left unit, while even number of zeros go to the right unit.

Decimal Point. To extract the square root of a number, it is necessary to start at the decimal point and pair off the given number, going right or left, into groups of digits.

The position of the decimal point is determined by the number of groups in the given number. For each group in the given number there is one place in the root, or answer.

241 has two groups, 2/41, or two places in the root.

81435 has three groups, 8/14/35 or three places in the root.

Example, obtain the square root of 64 = 8 .

Square Root	A	64 Right Unit
	D	8

There is one group of digits in the number 64, so there will be one place in the answer, the root. Since the number has an even number of digits the right unit of A scale was employed.

Example, obtain the square root of 1.44 = 1.2

Square root	A	144, Left unit
	D	12

There is only one group in the whole number. Therefore, the answer will have one place and the left unit will be employed.

Example, obtain the square root of 0.055 = 0.235

Square root	A	0.055 Left unit
	D	0.235

There is one zero between decimal point and first figure so the left unit was used. The decimal point is placed before the first figure of the answer.

Example, obtain the square root of 0.000046 = 0.00678

Square ~~Sauqre~~ root	A	46 Right Unit
	D	678

Since there are an even number of zeros and two groups of seros, the right unit is used and two zeros.are placed between the decimal point and the first figure of the root.

When the square root is to be multiplied, or divided, by one or more factors, it is advisable to obtain the square root first, then multiply, or divide, by the root by the factor or factors, using the C and D scales.

Either estimate the position of the decimal point or it may be found by the combined methods of sqqare root and the projecting of the slide.

Example, find the value of $40\sqrt{53} = 288$

Multiplication and Square Root	A		53 Right Unit
	C	40	1
	D	288 answer	Square Root

Since 53 has an even number of digits, the right unit of A scale was used. The runner or index locates the root of one number on the D scale. This is multiplied by 40 of the C scale and under 30 is the answer, 288. The answer has three digits as the sum of the digits of 40 and the root, slide projecting to the left, is three.

Example, find the value of $\sqrt{385} \div 32 = 0.613$

Division & Square Root	A	385 Left unit	
	C	32	1
	D	Square root	613 answer

Since 385 has an odd number of digits, the left unit is employed. Its square root, of two figures, is held by the runner to the D scale. Over the root, on C scale, the divisor 35 is placed, and under the index of C is the answer, 613. The difference between the number of digits in the divident, 2, and the divisor, 2, is zero, 2-2=0. Therefore, there are zero digits in the quotient.

In extracting the square root of products or quotients, estimate the number od digits there will be in the product or quotient. This estimation determines which unit of A scale to employ.

Example, find the value of $\sqrt{50X6} = 17.3$

Square root of a product			
	A	Product	6
	B	50	1
	D	17.3answer	

Since the product of 50 X 6 will have a three digit or odd number of digits in the answer, the left unit of A scale will be employed. Therefore, the multiplication will be done on the A and B scales under the product, of 3 digits on the A scale, is found the root of 2 digits on the D scale.

Example, find the value of $\sqrt{875} \div 35 = 5.0$

Square root of a quotient			
	A	Quotient	875
	B	1 center Index	35
	D	5, answer	

By an estimation, the quotient of $875 \div 35$ has two digits. Therefore, the right unit will be employed for the division as well as the extracting of the square root, and the root will have one digit.

Exercise 11

Find the Value of

1. $\sqrt{5}$
2. $\sqrt{8}$
3. $\sqrt{14}$
4. $\sqrt{3.14}$
5. $\sqrt{66}$
6. $\sqrt{80}$
7. $\sqrt{314}$
8. $\sqrt{428}$
9. $\sqrt{800}$
10. $\sqrt{785}$
11. $\sqrt{0.45}$
12. $\sqrt{0.765}$
13. $\sqrt{0.0314}$
14. $\sqrt{0.001235}$
15. $\sqrt{0.00045}$
16. $8\sqrt{8}$
17. $7\sqrt{19}$
18. $2.1\sqrt{40}$
19. $36\sqrt{53}$
20. $44\sqrt{31.4}$
21. $66.5\sqrt{75.5}$
22. $1300\sqrt{4100}$
23. $3.1416\sqrt{8400}$
24. $7.5\sqrt{3.1416}$
25. $41\sqrt{8000}$

26. $\sqrt{0.8754} \div 16$

28. $\sqrt{405} \div 5.1$

28. $\sqrt{17.3} \div 26$

29. $\sqrt{144} \div 0.144$

30. $\sqrt{0.09} \div 0.00062$

31. $24 \div \sqrt{1.75}$

32. $17.5 \div \sqrt{408}$

33. $4.52 \div \sqrt{2100}$

34. $12 \div \sqrt{7854}$

35. $0.57 \div \sqrt{0.041}$

36. $0.031 \div \sqrt{0.0075}$

37. $0.006 \div \sqrt{0.0048}$

38. $8.75 \div \sqrt{0.000175}$

39. $11.48 \div \sqrt{8.45}$

40. $99 \div \sqrt{405}$

41. $\sqrt{40 \times 83}$

42. $\sqrt{14 \times 77}$

43. $\sqrt{125 \div 17}$

44. $\sqrt{480 \div 16}$

45. $\sqrt{24.8 \div 17.25}$

46. $\sqrt{\dfrac{2 \times 4 \times 7}{5 \times 8}}$

47. $\sqrt{\dfrac{20 \times 41 \times 82}{40 \times 62 \times 3}}$

48. $\sqrt{\dfrac{67 \times 25 \times 12}{84 \times 70 \times 33}}$

49. $\sqrt{\dfrac{45 \times 3.14 \times 0.05}{91 \text{ E } 0.8 \times 0.62}}$

50. $\sqrt{\dfrac{14 \times 0.015 \times 0.95}{0.76 \times 40 \times 0.785}}$

The 2/3 Power

Occasionally a number is required to be raised to the two-thirds power. To do this, use the K and A scales. To find the 2/3 power of a number, place the runner over the given number on the K scale and follow upward to the A scale to find the answer. For example, find the value of 64 raised to the 2/3 power, (written $\sqrt[3]{64^2} = 16$). To solve, place the runner over 64 on the center unit of K scale, and read the answer 16 on right unit of A scale.

Find the value of $\sqrt[3]{216^2}$, $\sqrt[3]{512^2}$, $\sqrt[3]{3.14^2}$.

The 3/2 Power

To find the 3/2 power, three-halves power, use the A and K scales. To obtain the 3/2 power of a number place the runner over the given number on A scale and follow downward to the K scale to find the answer. For example, find the value of 9 raised to the 3/2 power, (written $\sqrt{9^3} = 27$) To solve, place the runner over 9 on the left unit of A scale and read the answer 27 on the center unit of K scale.

Find the value of $\sqrt{25^3}$, $\sqrt{49^3}$, $\sqrt{3.14^3}$.

The 4th Power and 4th Root

The fourth power of a number is the equivalent to the square of the square of a given number. Thus, $4^4 = 256$, or $4^2 \times 4^2$, or $4 \times 4 \times 4 \times 4$. To solve, place the runner to 4 on the D scale and read the square on the right unit of A, 16. Then replace the runner to 16 on the D scale and read the answer 256 on the A scale.

Solve for 3^4, 7^4, 3.14^4, and 8^4.

The fourth root of a number is the reverse of the above which is the extracting the square root of a number and then extracting the square root of that result. Thus, the fourth root of

16 = 2, (written $\sqrt[4]{16} = 2$). To solve, place the runner 16 on the right unit of A scale and read the square root on the D scale, 4. Set the runner to this 4 on the left unit of the A scale and follow downward to the D scale to read the answer 2.

Solve for $\sqrt[4]{625}$, $\sqrt[4]{3.14}$, $\sqrt[4]{2401}$, and $\sqrt[4]{81}$

Chapter XI.

Reciprocals and Percentages

Reciprocals

The reciprocal of a number is obtained by dividing 1 by the numbe?. The reciprocal of 4 is $\frac{1}{4}$ or .25 The reciprocal of 25 is 1/25 or 0.04. 1/20 or 0/05 is the reciprocal of 20.

The reciprocals are found on the C and CI scales or the CI and D scales. When the runner is set to a number on the CI scale, the inverted scale, read the reciprocal directly under it on the C scale. If the number is on the C scale, read the reciprocal directly above it on the CI scale. A similar relation exists between the CI and D scales, but be sure that the indices are in line.

To determine the decimal point in whole numbers, the reciprocal of the number has as many zeros between the point and the first figure as is one less than the number of digits in the given number. In decimals, the number of digits in the reciprocal is one more than the number of zeros between the point and first figure of the given number.

Thus, what is the reciprocal of 6? the answer is 0.167.

Reciprocal	CI	167
	C	6

What is the reciprocal of 0.05? The answer is 20.

Reciprocal	CI	20	1
	D	0.05	1

Exercise 12.

Reciprocals, Using CI and C, or CI and D scales

1. 3
2. 5
3. 7
4. 12
5. 125
6. 75
7. 1.50
8. 94.5
9. 7.52
10. 0.084
11. 0.144
12. 0.0048
13. 0.00109
14. 0.56
15. 3.25
16. 3.14
17. 1.44
18. 9.45
19. 620
20. 356
21. 144
22. 0.0109
23. 0.0945
24. 84.5
25. 54.2

Percentage

Percentage is the work of multiplication or division. The usual way to determine the position of the decimal point is the same as in multiplication and division. The C and D scales should be used for they afford greater accuracy.

The three basic questions involving percentages are,

First, What per cent of 80 is 40?

The answer is 50%. Thus, 40/80 X 100 = 0.50

%			
	C	80	1
	D	40	50%

Second, What is 25% of 340? The answer is 85. Thus 0.25 X 340 = 85.

%			
	C	1	340
	D	25%	85

Third, find the number of which 47 is 81%. The answer is 58. Thus, 47/.81= 58.

%			
	C	81%	1
	D	47	58

Per cent means "in the hundredths" in Latin.

To reduce decimals to per cents, move the decimal point two places to the right.

To reduce per cents to decimals, move the decimal point two places to the left.

To reduce a fraction to per cents reduce the fraction to a decimal and then read the decimal as per cents.
Thus, $\frac{1}{4} = 0.25 = 25\%$

Change each of the following to a per cent

1/3 1/2 2/3 1/4 2/5 3/8 5/8 2/7 5/12 7/10 1/30. 11/20 3/11 4/5 7/9 6/14 7/12 13/15

Change each to a common fraction

15% 9% 2% 1% 25½% 7½% 12½%

What is, 40% more than 85?
15% more than 140?
20% more than 320?

What is 80% less than 240?
75% less than 150?
62½% less than 2200?

Exercise 13.

Using the C and D Scales.

1. What per cent of	2. Find the Value of	3. Find the number of Which
1. 32 is 8	11. 10% of 400	21. 144 is 12%
2. 35 is 7	12. 12% of 84	22. 300 is 40%
3. 144 is 12	13. 43% of 125	23. 150 is 13.8%
4. 125 is 5	14. 18% of 314	24. 650 is 42%
5. 40 is 1.25	15. 67% of 144	25. 85 is 90%
6. 840 is 240	16. 53% of 945	26. 38 is 47%
7. 625 is 550	17. 80% of 720	27. 125 is 65%
8. 34.5 is 57.5	18. 92% of 652	28. 980 is 11.5%
9. 43.4 is 0.95	19. 27% of 72	29. 88 is 75.5%
10. 0.75 is 0.0012	20. 41% of 844	30. 1070 is 12.5%

Chapter XII

Variations

The problems in variation are in general applicable to the C and D and CI and D scales. When the decimal point position is to be determined and estimation is not the chosen method the rules for the projecting slide apply to problems in variation.

Example: if the weight of a wire varies directly as its length and 40 feet weighing 2½ pounds, what is the weight of 320 feet of this wire?

Variation	C	40	1
	D	320	8

Then

Variation	CI	1	2½
	D	20 answer	8

Exercise

1. If a bus ticket costs $4.00 for 500 miles, what is the cost of a bus ticket for 150 miles?
2. The daily wage at a factoryis $5.50. What is the salary for 12 day's work?
3. If the cost of meat is $1.80 for 5 pounds, what is the cost of 8½ pounds.
4. The current of a river flows 2¼ miles an hour. What time would be needed to drift with the current, other forces being equal, for 3 3/4 miles?
5. Eight men can do a piece of labor in 14½ days. How many days will it take 12 men to do the same piece of work?

6. If the speed of a train is 45 miles an hour, how far will it travel in 2 hours and 15 minutes?

7. Forty-four pounds of nails cost \$3.52. What is the cost of 18 pounds?

8. Nine and one half dozen eggs cost \$4.75. How many dozen may be bought for \$11.25?

9. If a Boy Scout hikes $7\frac{1}{2}$ miles in $3\frac{1}{2}$ hours, how many hours does it take him to hike 5 miles?

10. Lumber costs \$85 for 2500 feet. What is the cost of 3500 feet?

Chapter XIII

Equivalents and Conversion Ratios

There are many problems requiring the value of a quantity.

There are many problems today which have one known quantity in terms of one unit which require to know its equivalent in terms of another unit, such as dollars to francs, gallons to liters, and square meters to square feet. There are many such conversion tables in general use today. These equivalants and ratios are suitable for computation on the C and D scales. The decimal points are to be estimated.

Thus, if the constant ratio 1/1.41 or 70/99, is placed on the C and D scales, any side of a square on the C scale will give the diagonal of that square on the D scale.

Conversion	C	Side of Square	1
	D	Diagonal of Square	1.41

By the same method of coupling upon the C and D scales, problems are readily solved involving the following equivalents and conversion ratio.

1. horsepower = 42.44 B.t.u's per min.
" = 550 foot lbs per sec.
" = 746 watts
$1.00(U.S.) = 5.2 francs
" = 4.2 marks
" = 0.205 pounds sterling
" = 4.11 shillings
1 fathom = 6 feet
1 fulong = 40 rods
1 knot = 1.152 miles
1 bushel = 1.244 cubic feet
1 " = 2150 cubic inches
" " = 4 pecks
" " = 64 pints (dry)

To find abs. temp. (degs.Cent) multiply temp. (degs. Cent) + 273 by 1.

To find temp. (degs. Fahr.) multiply temp. (degs.Cent) + 17.8 by 1.8

To find abs. temp. (degs. Fahr.) multiply temp. (degs. Fahr.) + 460 by 1.

To find temp. (degs. Cent.) multiply temp. (degs. Fahr.) - 32 by 5/9.

Exercise 14.

Equivalents and Conversion Ratio. Using the C & D. Scales

1. Find the number of gallons of water in a container holding,
   (1 gal. is equivalent to 3790 cu.cm.)

   3200 cu.cm. of water
   8640 " " "
   160 " " "
   5300 " " "
   1280 " " "

2. How many square feet are there in a piece of lumber,
   16' long 4" wide, 1" thi
   8' " 9" ",
   12 " 6" "
   14 " 5" "
   10 " 10"

3. If nails costs ... many pounds can be
   brought for
   $4.30
   $7.40
   $11.25
   $15.00
   $25.00

4. If there are 5280 to an ordinary mile and 6080 feet in
   a nautical mile, how many nautical miles are there in
   11,450 feet?
   37,100 "
   17.5 "
   41.6 "
   73 "

Exercise 14.

Equivalents and Conversion Ratio.Using the C & D.Scales

1. Find the number of gallons of water in a container holding,

(1 gal. is equivalent to 3790 cu.cm.)

3200 cu.cm. of water

8640 " " "

160 " " "

5300 " " "

1280 " " "

2. How many square feet are there in a piece of lumber,

16' long 4" wide, 1" thick?

8'	"	9"	",	1"	"
12	"	6"	"	2"	"
14	"	5"	"	1"	"
10	"	10"	"	10"	

3. If nails costs 8 3/4 cents a pound, how many pounds can be brought for;

$4.30

$7.40

$11.25

$15.00

$25.00

4. If there are 5280 to an ordinary mile and 6080 feet in a nautical mile, how many nautical miles are there in

11,450 feet?

37,100 "

17.5 "

41.6 "

73 "

5. If there are 39.37 inches in one meter, how many inches are there in

3.4 meters

43 "

7 yards

9.5 "

31 "

6. If 1 meter = 1.1 yard

1 kilometer = 5/8 miles

1 inch = 2/54 centimeters

1 mile = 1.6 kilometer

1 kilogram = 2.2 lbs.

solve the following.

84 meters equal how many yards?

3.1416 meters equal how many yards?

4.5 kilometers equal how many miles?

75 kilometers equal how many miles?

9.5 inches equal how many centimeters?

144 inches equal how many centimeters?

21.5 miles " " " kilometers?

44 miles " " " "

105 kilograms " " " pounds

345 " " " " "

7. If there are 7.47 U.S.gallons to 1 cubic foot, how many gallons are there in 0.5 cubic foot ?

8.5 cubic feet ?

12.5 " "

204 " "

310 " "

8\. If 1 gallon = 3.78 liters

1 ounce = 28.3 grams

1 cubic inch = 16.4 cubic centimeters.

Change 85 gallons to liters

change 125 leters to gallons

Change 16 ounces to grams

Change 104 grams to ounces

Change 12.4 cubic inches to cubic centimeters

180 cubic centimeters to cubic inches

9\. If 1cord = 128 cubic feet

1 gallon = 231 cubic inches

1 rod = 16.5 feet

1 acre = 43560 square feet

1 acre = 160 square rods

Change 3.5 cordsto cubic feet

" 528000 cubic feet to cords

" 5.2 gallons to cubic inches

" 4200 cubic inches to gallons

" 16 rods to feet

" 322 feet to rods

" 1.5 acres to square feet

" 0.8712 square feet to acres

" 5 acres to square rods

" 200 square rods to acres

Chapter XIV.

Simple and Compound Interests

To compute problems of simple interest, I, and the amount of time when time is expressed in years, T, multiply the principal, P, by the rate of interest, R, by the time, T. Thus I = PRT.

The C and D scales or the Ci and D scales are best suited for such problems. The rule of the projecting slides is applicable in determing the position of the decimal point. An estimate beforehand, however, is equally as good, if not a better method.

Example: Find the interest on $5,000.00 at 6% for 4 years.

Interest 1 year	C	5000	1
	D	300 answer	0.06

Then,

Interest 4 years	C	300	1
	D	1200 answer	4

Computing Compound Interest.

What is the compound interest on $5,00 for 3 years at 5% with semiannual interest periods? In this solution there are five steps to follow: first step: find the interest for the first period. The annual rate is 5%; the semiannual rate is 2½% or 0.025%. $5,000 X 0.25 = $125.00. Second step: the amount now would be $5,000 + $125.00 = $5,125. Third step: compute the interest on this amount for the second interest period. $5125 X 0.024 = $128.13. Fourth step: by adding this second interest period, the amount is $5125 + $128.13 = $5253.13. Fifth step: continue this last process until each of the 6 periods have been computed. Sixth step: subtract the original amount, $5000, from the final result, $5,798.48, giving the compounded interest, $798.48.

Since the description above represents the usual method, the braille slide-rule computation may be made easily by the following procedure.

Find the compound interest on $800 at 3% for 3 years. Find the interest for each year and mentally add it to the principal. Since these steps involve straight multiplication, the CI and D or C and D scales are used. The A and B scales would not give the desired accuracy.

3% of $800 = $24.00, $800 + $24 at end of 1st year.

3% of $824 = $24.72, $824 + $24.72 at end of 2nd years.

3% of $848.72 = $25.46, $848.72 + $25.46 at end of 3rd year.

$874.18 - $800 = $74.18, the compounded interest for a 3 year period.

Exercise 15.

Find the interest on

1. \$350. at 3% for 1 year.
2. \$400. at 4% " " "
3. \$425. " 5% " 2 "
4. \$650. " 6% " 2 "
5. \$720. " 6% " 2½ "
6. \$1200." 4% " 3¼ "
7. \$800. " 3½% " 2¼ "
8. \$600. " 4 3/4% 3 3/4 years
9. \$2,000" 1½% for 5¼ years
10. \$2500 " 6% " 4½ "

Find the principal which will

11. Earn \$25. at 6% in 1 year
12. " \$40. " 5% " ½ "
13. " \$60. " 5% " 120 days
14. " \$80. " 3% " 30 days
15. " \$1200 " 4½% "180 "

Find the time necessary for

16. \$300. to earn \$21 at 2%
17. \$450 " " \$18. at 1%
18. \$625 " " \$42. " 5%
19. \$550. " " \$120 " 4%
20. \$800. " " \$160 " 6%

Exercise 16.

Find the amount and the compound interest on the following sums:

1.	$250. at	5%	for	4	years,	compounded	annually.
2.	$2000."	6%	"	3	"	"	"
3.	$4500."	4%	"	5	"	"	"
4.	$8000."	4%	"	2	"	"	semiannually.
5.	$6000."	6%	"	4	"	"	"
6.	$3500."	2%	"	5	"	"	annually.
7.	$10,000"	1½%	"	8	"	"	"
8.	$1200 "	2½%	"	7½	"	"	"
9.	$1500 "	3½%	"	5¼	"	"	"
10.	$1800 "	4½%	"	6½	"	"	"

Chapter XV.

Circumference and Diameter of the Circle

In this field of work, the A,B,C and D scales are generally used. The two special markings 3.1416 and 0.7854 on the A and B scales are helpful.

Example: to find the area of a circle whose diameter is 4, place 0.7854 of B to the right index of A scale opposite 4 on D scale, read the answer 12.57 nearly, on the B scale. To this setting, opposite any diameter on the D scale, read the area on the B scale. Thus, Area

A rea	A	1257	1 Right Index
	B	4	0.7854

Example: to find the circumference of a circle whose diameter is 1.43, place left index of B to 1.43 on A scale. Opposite 3.1416 on the B scale, read the circumference 4.5 approximately, on A scale. Thus,

Circumference	A	1.43	4.5
	B	1 left index	3.1416

Symbols.

A is the area

C is the circumference

D is the diameter

R is the radius

V is the volume

Formules

$C = D \times 3.1416$

$D = C \times .31831$

$A = D^2 \times 0.7854 = 3.1416 \times R^2$

$R \neq \times 6.283 = C$

$C^2 \times 0.07958 = A$

$\frac{1}{2} C \times \frac{1}{2} D = A$

$C \times 0.15915 = R$

VA X 0.564 = R

VA X 1.128 = D

A of sphere = $D^2 \times 3.1416$

V of sphere = $D^3 \times 0.5236$

2D = 4Xpipe capacity

Exercise 17.

1. Find C when D = 6
2. Find C when D = 3.4
3. Find R when C = 44
4. Find C when D = 82
5. Find R when c = 185
6. Find R when C = 2000
7. Find A when D = 17
8. Find A when D = 65
9. Find A when D = 72
10. Find D when A = 15
11. Find D when A = 255
12. Find D when A = 1125
13. Find R when A = 14
14. Find R when A = 66
15. Find R when A = 125
16. Find A when R = 5
17. Find A when R = 0.75
18. Find A when R = 0.125
19. Find A when R = 72.0
20. Find V of a sphere when D = 2
21. Find V of a sphere when D = 40
22. Find V of a sphere when D = 5.1
23. Find A of a sphere when D = 5
24. Find A of a sphere when D = 1.2
25. Find A of a sphere when D = 80

Chapters I and II reflect in a parallel way the early beginnings of the logarithmic slide rule and the braille reading system for the blind. These two separate products of social inheritance through centuries of work are welded together in the braille slide rule. This instrument, which gives the blind skills beyond the present methods of arithmetical computations, is but one part of Napiers logarithms which lays the foundation extensively for modern computations.

Many scientists are included in the manual for their contributions are in some way related to the present instrument. Then, too, illustrations are given of the various systems of reading by the blind,

The Moon type

The New York Point

The American Braille

The Standard Braille

The latter is the dominant and universally adopted system of reading by the blind today.

The next two Chapters III and IV, give important preliminary principles and necessary information to the use of the braille slide rule. These chapters lay the foundation for accurate reading of the braille slide rule, a fundamental of prime importance. Accuracy brings about speed, the factor so badly needed today in arithmetical computations by the blind.

The only pictures of the braille slide rule are found here. Also, the three unit or cube scale and the inverted scale, K and CI scales respectively, are graphically portrayed with braille numerals.

The balance of the manual concerns itself with the procedures in acquiring the use of the new instrument. The model problems and exercises give special consideration to difficulties in fundamental reading of the secondary and tertiary figures and placement of the decimal point without which students would find difficulties and abandon the attempts to acquire the use of the braille slide rule. After a survey was made of modern textbooks in arithmetics, the topics or chapters were selected, grouped, and treated separately, namely

Multiplication
Division
Combined Multiplication and Division
Figuring Costs
Ratio
Proportion
Conversion Ratios
Squares and Root
Cubes and Root
The 2/3 and 3/2 Powers
The 4th Power and Root
Reciprocals
Percentages
Variations
Equivalents
Simple and Compound Interests
Circumference and Diameter of Circles

Each topic or chapter contains a series of problems pertinent to that topic with a total of 66 diagrams for the beginner and nearly 500 problems graded from the simple to the

complex. These chapters,

Provide the teacher and student with a suitable supply of problems in exercises for both classroom and homework practice,

Provide for both the mental estimation for the decimal point location and sound rules applicable to the location of the decimal point in braille slide rule computations.

Provide a sufficient number of exercises, from the simple to the complex, to assure ample material for both initial teaching and remedial work.

Provide a method of learning, above and beyond that of random trial-and-error activities, which results in saving the psycho-physical energies of both the teacher and student.

Provide the teacher with a scale of exercises after each topic prepared in the order of difficulty, from the simple to the complex, in both arithmetic and braille slide rule reading.

Provide a smooth transition from one topic or unit of work to another and maintain a simple presentation of the manual for the blind student himself.

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